Supporting Information for "Controls on circulation, cross-shelf exchange and dense water formation in an Antarctic polynya"

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Introduction

The supporting material within this document provides details of the specified *a priori* errors used to derive the final inverse model solutions, as well as the model sensitivity to variations in those errors.

a priori errors

The *a priori* error in the solution, v_b, is set to 0.003 m s^{-1} (an order of magnitude less than the calculated $v_r \approx 0.03$ m s^{-1}), while the *a priori* error of the diapycnal velocity, w, is set to 1×10^{-5} m s^{-1} in summer and 5×10^{-4} m s^{-1} in the 1999 winter case. The diapycnal velocity *a priori* error is smaller than the horizontal velocity *a priori* error, in proportion to the expected velocity magnitude. The larger diapycnal velocity *a priori* error in winter reflects the expectation of larger diapycnal fluxes in winter, when surface

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buoyancy loss is large. The sensitivity of the solution to the choice of *a priori* error is discussed below.

A priori equation errors are set to $0.01\times C$ Sv in each layer (an order of magnitude below the absolute layer transport; order $0.1\times C$ Sv) and $0.1\times C$ Sv for the total box conservation in summer cases, where C is the layer-wise/total property concentration of mass, heat or salt. The *a priori* error of the total box conservation equations in winter are: 0.0047 Sv, 0.017 Sv °C and 0.00006 Sv psu for mass, heat and salt respectively; the *a priori* error for mass in each layer is 0.001 Sv. These errors are not the expected error in the transport estimates, but are chosen to allow each of the imposed surface buoyancy fluxes (Section 2.2.1) to remain within 20% of the prescribed values, while maintaining the 0.1 Sv total box mass flux error, thus ensuring the surface buoyancy flux input to the region represents that expected for winter conditions. An additional constraint, accounting for the shallowness of the northern 1999 section is also applied, bounding the total section transport to ± 0.2 Sv.

Solution sensitivity

The sensitivity of the solution has been explored through investigating the circulation dependence to variations in the *a priori* errors (Figure 1). Changing the *a priori* errors, as with any inverse model, has the potential to lead to aphysical solutions, and some prior understanding of the expected circulation is required to suitably constrain a model. The large destruction of DSW, rather than formation, in the 1999 case (Figure 1a) for increased *a priori* error of v_b and decreased *a priori* equation error, is highly aphysical given the expected strong surface buoyancy losses in winter. Further, under these two *a priori* error changes, circulation exists in which large variation occurs over small horizontal distances (up to 1 Sv over 8 km), illustrating unrealistically large variability. Due to such intuitively aphysical circulation for the conditions expected in this region, these error bounds are not considered sufficient to constrain the inverse model. For all other changes in the *a priori* errors, the circulation structure and magnitude remain consistent to that described in Section 3 and 4. That is, a strong northwestward and weak southeastward flow in summer (2001, 2015), with a nearly balanced northwestward and southeastward flow in winter (1999). Diapyncal fluxes remain weak in all summer cases and are strongly enhanced in winter. Hence, within the range of physically realistic solutions, the consistency of the results suggest our solution is a robust representation of the regions circulation.

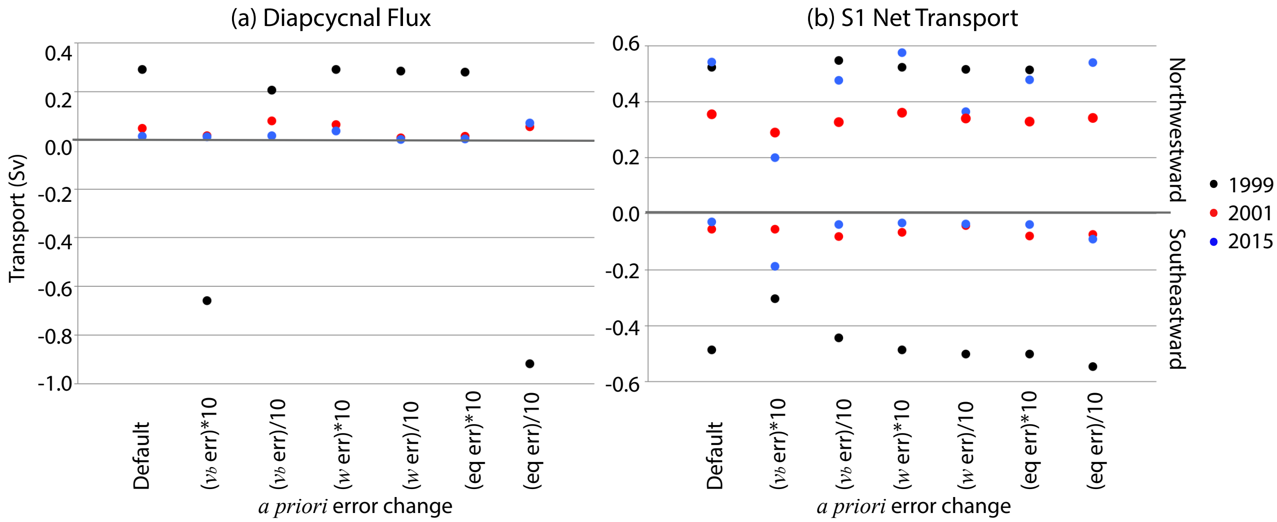

Figure 1. (a) Total DSW (1999, black) or net positive (2001, red; 2015, blue) diapycnal flux and (b) northwestward (positive) and southeastward (negative) transport through S1 for years 1999 (black), 2001 (red) and 2015 (blue) under an order of magnitude change in the *a priori* error estimates. The *a priori* errors of horizontal velocity (v_b), diapycnal velocity (w), and the equations (eq) are increased and decreased by an order of magnitude in each case. Note, the increased v_b error and decreased equation error results for transport through S1 in 1999 are not shown, due to unrealistically large results (see text for details).